Using ZigBee low-power wireless standard for monitoring patients' signs

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Abstract. This paper presents Wireless Body Area Network (WBAN) strengths and gives an understanding of what possibilities they have when using short range wireless communications protocols to facilitate versatility in the movements of health care patients. The comparison made between the wireless standards and technologies used in such systems using qualitative measures gives insight into potential opportunities for their usage. The paper investigates the feasibility of using the ZigBee protocol and findings are implemented on presented COHESY system model for continuous real time remote patients monitoring conditions.

Keywords: Wireless Body Area Network, real time monitoring, ZigBee

1 Introduction

Pervasive health care takes steps to design, develop and evaluate computer technologies that help citizens participate more closely in their own healthcare, on one hand, and on the other to provide flexibility in the life of patients. By including collaborative value in these systems patients are enabled to exchange experience in terms of therapy and rehabilitation by using the experience of the activities that have been taken by other patients. System model COHESY uses mobile, web and broadband technologies, so the citizens have ubiquity of support services where ever they may be, rather than becoming bound to their homes or health centers [6].

Recent improvements in low-power wireless communications have motivated great interest in the development and application of wireless technology in healthcare and biomedical research, including Wireless Body Area Networks (WBAN). As result

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of this, various systems that demonstrated the successful transmission of bio signals are created.

C-SMART [1] is a platform for a continuous real time remote patient monitoring, it uses Bluetooth for transmitting signals from sensors to mobile devices. Application send the raw data continuously via e-mail or SMS to a remote computer for monitoring and analysis. After data analysis, medical records are updated and the result is send back to mobile device.

Wireless Sensor Network based Health Care Management Platform for Long-Term Care Institution [2] proposes a safety monitoring system for health care management that incorporates ZigBee humidity sensors. Electronic humidity sensors help to provide appropriate care to disabled and incontinent elders.

Digital Fitness Connector (DFC): Smart Wearable System [7] allows users to monitor physical activity either in real-time or post workout using ANT+ sensors. DFC gives user flexibility to carry smartphone only if they wish to monitor physical activity real-time, otherwise users can just carry DFC to capture and store data from health and fitness sensors.

In [8], a prototype on RFID and sensor networks for elder healthcare is presented. The RFID system, including a reader and one or more tags are used to track the elder patient who needs the medicines. The patient wears a UHF tag that may be detected by the associated RFID reader within 3-6 meters. Thus, the system is able to determine that the patient is in the vicinity, and alerts the patient to take the required medicines via a beep sound or a blinking light.

The work presented in this paper attempts to probe into the applicability and practicality of using WSN based on ZigBee protocol. The presented solution is a COHESY system model which is designed for continuous healthcare of patients allowing them to perform their daily obligations; work, walks etc. Because of this characteristic, its intent is to wide range of patients, like: working capable people, children, and elderly patients, which makes it more comprehensive than other systems. COHESY offers connection to social network which consists of patients with similar diagnosis, which makes it different than other systems. Its other characteristic that makes different is that it has collaborative techniques for filtering data from information systems and social network, which allow the user to get notifications, suggestions and proposals, from medical personnel and other patients with similar diagnosis, at any time during the day.

Analysis of low-power WSN standards is presented in the next section. General architecture is discussed in third section and in the fourth section architecture of sensor layer in given. The fifth section explains implementation details while the sixth section concludes this paper.

2 Analysis of low-power WSN standards

When dealing with a broad range of possible application, the key issue regarding the sensor networks is the scalability in terms of range, battery life, frequency, and transmission rate. For that reason we are examining short range wireless communications

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with low power consumption. The proposed standards with such features are: RFID, Bluetooth, ZigBee, and ANT+. Table1 summarizes the main differences among them.

Standard	Range	Frequency	Battery life	Transmission rate
RFID	1-2 m	860-960 MHz	efficient power	96-256 bit/s
Bluetooth	10 m	2.4 GHz	1-7 days	1000 kbit/s
ZigBee	100 m	2.4 GHz	4-6 mounts	250 kbit/s
ANT+	30 m	2.4 GHz	3+ years	1000 kbit/s

Table 1. Overview of wireless standards [3]

Bluetooth and ZigBee have limited battery power which makes them suitable for low data rate transitions only [5]. ANT+ and RFID are best suited for relatively small networks because of their small coverage range. And ANT's technology offered significant advantages over ZigBee for short range wireless sensor implementations requiring low power operation. ZigBee have good efficiency for small data size and it can transmit up to 250 kbits at 2.4 GHz which is sufficient data rate for typical WBAN applications and their usage in medicine. ANT+ uses a radio with a bandwidth of 1Mbps while ZigBee employs one based on the IEEE802.15.4 standard with a bandwidth of 250 Kbits. The ANT+ module has the longest battery life which is essential for a practical wireless network because the batteries powering nodes need to last for months/years to minimize maintenance and because its substantial transmission rate can be considered for a long term continuous use.

The main criteria are why we choose ZigBee protocol in COHESY: The wide range of activity makes it possible to receive data from the sensors in the case when the mobile device is not close to the user. The amount of data that is read from the sensors is small, so there is no need to be taken to support the large amount of data, but a high-speed transmission allows timely calculations without delay. And battery life lasts for months, which is acceptable for medical applications.

3 General Architecture

Collaborative Health Care System Model (COHESY) [9] is intended to allow continuous real time monitoring of the patient's conditions without restriction of movement and their daily activities. Its platform is designed at first to allow detection of unwanted results and any irregularity in patient movements in order to stop in time, and as second to use experience from other patients to give appropriate recommendation to the new ones. The system consists of a WBAN, mobile device, information systems, and social network. The general architecture is shown in figure 1.

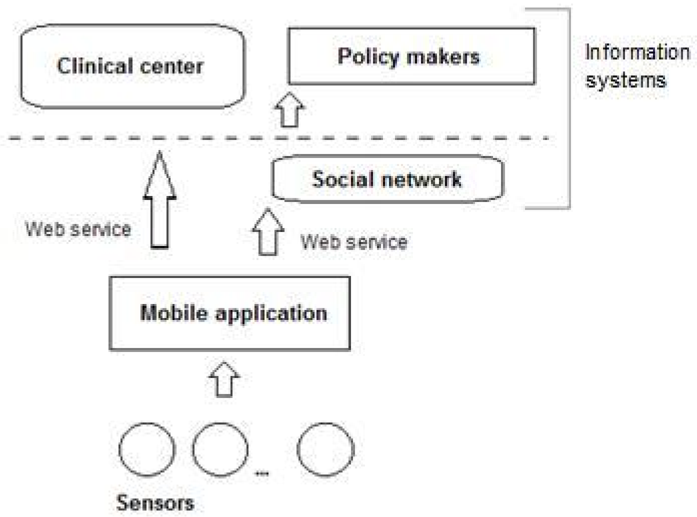

Fig. 1. General architecture

The WBAN comprises a number of wireless sensor nodes and mobile device. The sensors are distributed over the user's body. They receive signals from the patient and sends data to network layer, which then forward measurement data to mobile device. The mobile application monitors the condition of patient. Its function is divided into two sub layers: aggregator layer and local calculator layer.

The aggregator layer is divided to three processes: (1) Collection: collects data from sensors, including sensors for physiological signs and any related sensors like, temperature, position etc.; (2) Filtering: filters previously collected data from any unused (noise) received information; (3) After this process data should be prepared for processing, they are settled in previous defined format and forwarded to the calculation layer.

Local calculator layer analyzes the data and reaches conclusions based on predefined rules. If there are unsatisfactory results, the patient will be informed by notification/warning message to mobile device, and he will receive explanation information (the reason for notification or recommendation). If the result is emergent then is send an emergency signal, mobile call or SMS to related care or medical treatment personnel to deal with the event. Patient is then informed with an alert message. In case where local calculations are not enough, data is sent to a clinical center for additional calculations. After determining procedures for the patient, his data is updated and the result is send back to his mobile device. In the process of sending, data is previously encrypted, which produce smaller data size and this has energy efficiency impact. To protect the privacy and confidentiality of the users' information from threats, data is sent though secured protocols. The sequence diagram for positive flow of system behavior is shown in figure 2.

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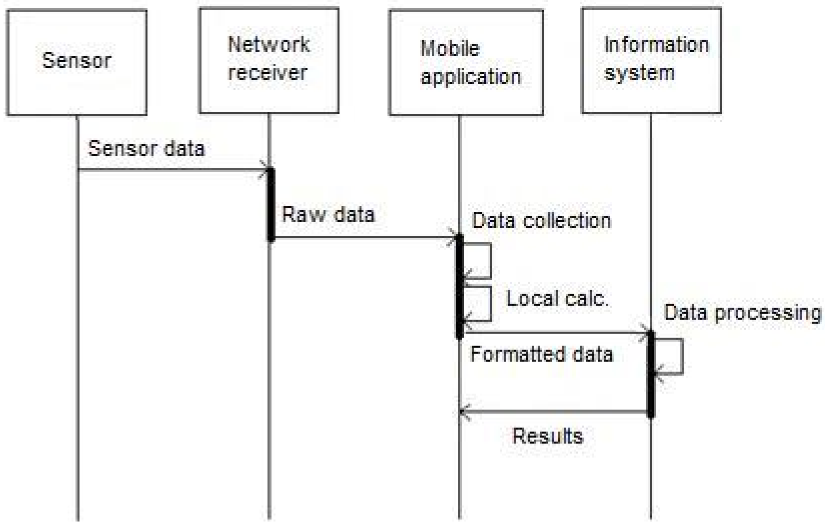

Fig. 2. Sequence diagram for process of sending sensor data

The information system performs functions on received data from mobile application. These functions include finding dependency between measured sensor data, for example: heart rate and patient movements, performing calculations that require more resources like memory or processor power. One of these operations applies collaborative filtering techniques in set of data, in order to give recommendation based on knowledge from other patients, cases and experience. The aim of the recommendation algorithm is to discover which activities affect change in the value of each health parameter individually. In this way the use has opportunity for professional concern about his health and self-care. [6]. The clinical center can be virtually anywhere in the world as long as it is reachable from the Internet, providing the following purposes:

- To communicate with the remote entities and to collect the data generated by the WBAN sensor nodes.
- Once the data collected, it can be stored in a database or file system with a certainformat, or it can be visualized and displayed in a graphical user interface, ordisplayed as web content.
- In the case where the data is stored in a database/file system, the data can be retrieved later and processed further to be used by authorized users (such as doctors, clinicians, physicians, researchers…etc) for purposes of inspection, diagnosis, research, statistics and so forth.

The social network consists of patients with related diagnosis; each of them has a profile with information about their personal characteristics, diagnosis, treatments, experience, and habits. The social network enables collaboration between patients based on collaborative filtering techniques, , thus connecting users with the same or

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similar diagnoses, sharing their results and exchanging their opinions about performed activities and received therapy. The users can also receive average results from the other patients that share same conditions in the form of notifications. These notifications can vary from the average levels of certain bio data calculated for certain geographical region, age, sex to the recommendation for certain activity based on the activities of other users. Collaborative filtering can be used to achieve different recommendations in these contexts [6]. Recommendation from social network is considered as the second level of recommendation; the first level is from medical personnel.

Policy makers receive data from social network based on filter criterions. Policy makers analyze data and give recommendation, make program and strategy for prevention of the health condition that was analyzed.

4 Architecture of sensor layer

The sensor layer consists of a set of sensors that measure the patient's vital conditions and any related conditions, like motion and temperature. Although the current system model only incorporates these sensors, other types of sensors like, EEG, EMG or blood sugar can easily be added to the system. The motion sensor can be used for monitoring body motions and gesture recognition, whilst the temperature sensor can be used to monitor body temperature or the temperature of the ambient surrounding the body. This layer receives signals from patient sensors (transforms analog into digital), and sends data to network at regular intervals or sometimes when it is forced by the patient or third person. The architecture of the sensor layer is presented in figure 3.

Fig. 3. Architecture of sensor layer

5 Implementation Details

COHESY system model choose layer architecture pattern [4], for this reason it is decomposed into groups of subtasks in which each of them is at a particular level of abstraction.

(1) Sensor Layer uses sensors for reading vital signals and any additional signals. (2) Network layer is based on ZigBee protocol for receiving data from sensors and propagates them to the mobile device. This layer is a mobile application which will

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support most of mobile platforms at server side; client side will be implemented on (HTML5 + JavaScript) so it can be used by majority of smartphones. Received data from sensors will be converted in JSON (JavaScript Object Notation) format. We choose this format because it is compact, simple and has faster transmission because it transfers less data. This format has predefined template where some of data will be mandatory while other will be optional. It allows uniformity and consistency. Example is shown in figure 4.


```
{
"patientData":{
        "sensorID": "10000",
 "properties":[
          {
        "vitalSignals": "bloodSugar",
        "value": "3",
        "required" : true
          },
          {
                "addSignals": "position",
                "value": "100"
                  }
            ]
}
}
```


Fig. 4. JSON data format

The security aspect will include using 128 bit hash encryption function for sending encrypted data to the clinical centers and social networks. This type of encryption takes less time than other encryption functions, encryption level is satisfied, and by the nature of data it is sufficient. Information systems may use PostgreSQL database for storing all patient data, including settings, medical history and diagnosis, daily activities. This database is an open source and based on features and satisfied requirements of this model of system. Data stored in this database is used for further analysis by researches. Data flow diagram is presented in figure 5.

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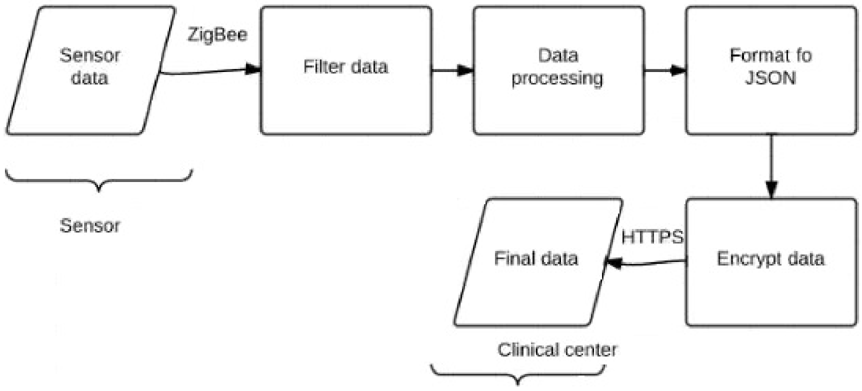

Fig. 5. Data flow diagram

6 Conclusion and future work

This paper presents implementation of ZigBee standards for a continuous real time patient monitoring of vital signs in the COHESY system model. The low-power nature of ZigBee sensors offers great potential in creating a wireless body area network for data collection within the body area. Its battery life of few months eliminates the need for even infrequent battery replacements or recharges. These characteristics allow the patient flexibility in movement and everyday activities. The main aid is timely detection of adverse outcomes in order to take preventive measures.

The presented model represents a successful first step towards the improvement of the quality of patient care. In this paper are also presented two ways of energy efficiencies: by applying filter techniques before data processing phase and data encryption before sending through Internet.

Future further aim of COHESY will be to improve software design and applying the methods for saving energy by implementing techniques for reducing data transfer from the sensor to the mobile device and applying of algorithms for filtering and encryption of the data from the mobile device to the information systems, so that COHESY can be expanded to become efficient monitor and control health care system in the future.

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